



Global Fit to Dark Matter with Leptophobic Mediators

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1. Introduction
2. Set-up and validation
3. General Results
4. Towards UV completions
5. Conclusions



1. Introduction

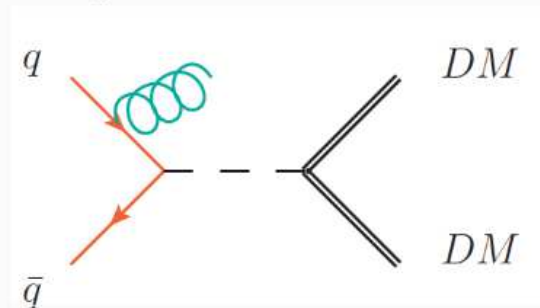
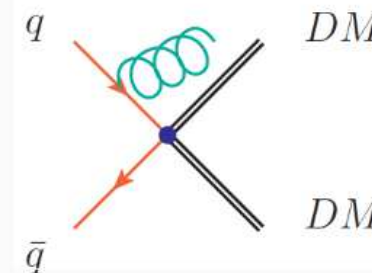
Dark Matter @ LHC

- We infer the existence of Dark Matter (DM) from indirect observations (cosmological, astrophysical).
- Can we probe DM at the LHC? Yes, if we assume that it couple sufficiently strongly to the SM (freeze-out points to that).
Unknown: the mass.
- DM searches at the LHC fully underway.



How to predict the signals and interpret the results? Different possibilities have been studied:

1. EFT approach.
2. *Dark Matter Simplified Models*
3. Complete models (e.g. SUSY).



[taken from E. Bagnaschi]

Approach at the LHC for DMSMs: example for spin-1 mediator

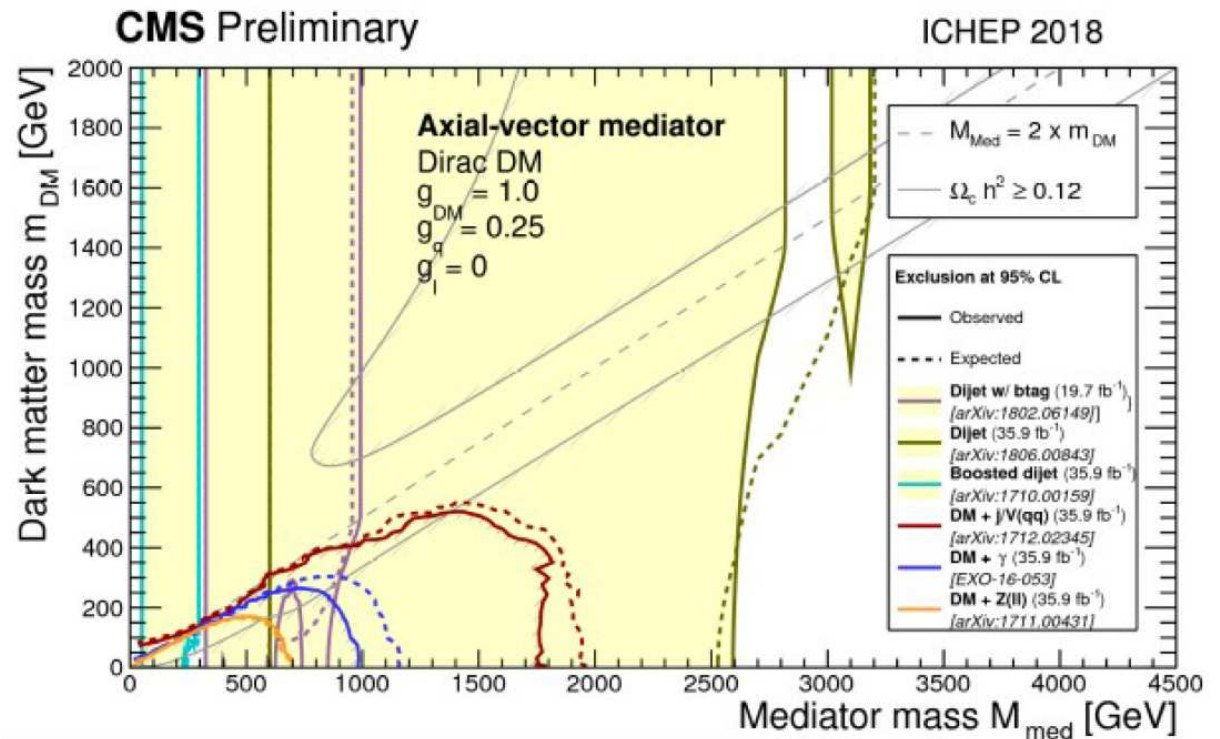
Spin-1 mediator

- Interaction Lagrangian mediator-DM

$$\mathcal{L}_{X_D}^{Y_1} = \bar{X}_D \gamma_\mu \left(g_{X_D}^V + g_{X_D}^A \gamma_5 \right) X_D Y_1^\mu.$$
- Interaction Lagrangian mediator-quarks

$$\mathcal{L}_{quarks}^{Y_1} = \sum_{i,j} \left[\bar{d}_i \gamma_\mu \left(g_{d,i,j}^V + g_{d,i,j}^A \gamma_5 \right) d_j + \bar{u}_i \gamma_\mu \left(g_{u,i,j}^V + g_{u,i,j}^A \gamma_5 \right) u_j \right] Y_1^\mu$$
- Interaction Lagrangian mediator-leptons

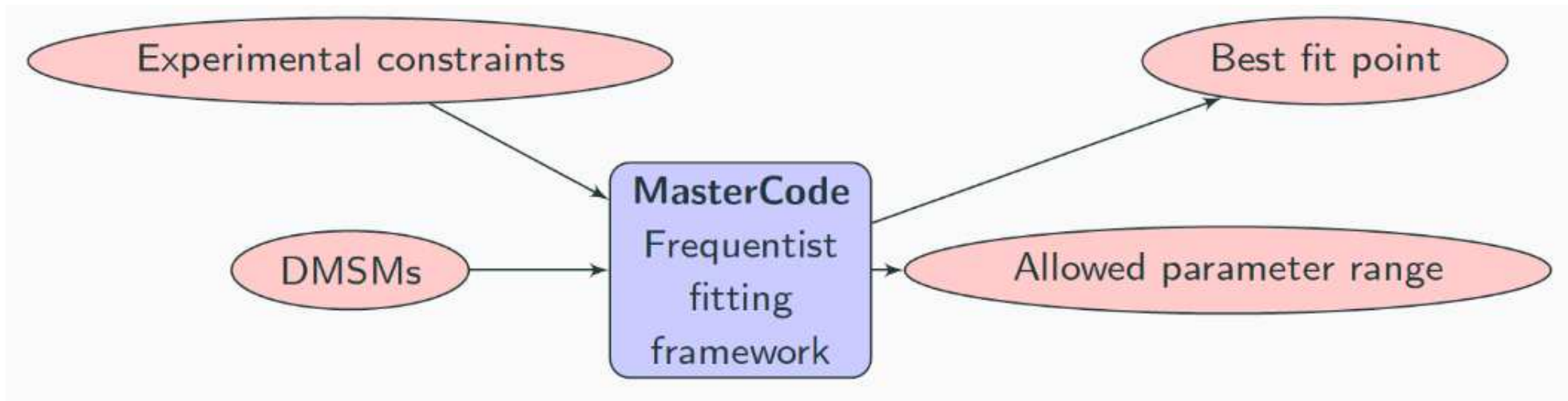
$$\mathcal{L}_{leptons}^{Y_1} = \sum_{i,j} \left[\bar{l}_i \gamma_\mu \left(g_{l,i,j}^V + g_{l,i,j}^A \gamma_5 \right) l_j \right] Y_1^\mu$$



- simplifying assumptions on the Lagrangian (more soon)
- Results for fixed values of m_{med} , m_{DM} , g_{SM} , g_{DM}
- overlay results from mono-jet search
- overlay results from di-jet searches
- . . .

MasterCode approach

Fit to the full Lagrangian (some simplifying assumptions)



Included into the fit:

- DM relic density
- DM direct detection limits
- LHC mono-jet searches
- LHC di-jet searches

⇒ global picture of status and prospects

2. Set-up and validation

Lagrangian according to LHC-DM-WG recommendation:

The Lagrangians

- We consider DMSMs with a spin-1 (Y_1) s-channel mediator.
- The dark matter candidate is a Dirac fermion (X_D).
- We use the model files provided by the DMSIMP package for our implementation.

Spin-1 mediator

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Scenarios

- Leptophobic, $g_{l_{i,j}}^V = g_{l_{i,j}}^A = 0$ (no constraints from dilepton searches).
 - Flavor diagonal, $g_{u/d_{i,j}}^{V/A} = 0$ if $i \neq j$.
 - Flavor blind, $g_{u_{i,j}}^{V/A} = g_{d_{i,j}}^{V/A}$.
1. $g_{X_D}^V \equiv g_{DM}$ $g_{X_D}^A = 0$
 $g_{u/d}^V \equiv g_{SM}$ $g_{u/d}^A = 0$,
pure vector.
 2. $g_{X_D}^V = 0$ $g_{X_D}^A \equiv g_{DM}$
 $g_{u/d}^V = 0$ $g_{u/d}^A = g_{SM}$,
pure axial-vector.

[taken from E. Bagnaschi]

MasterCode set-up :

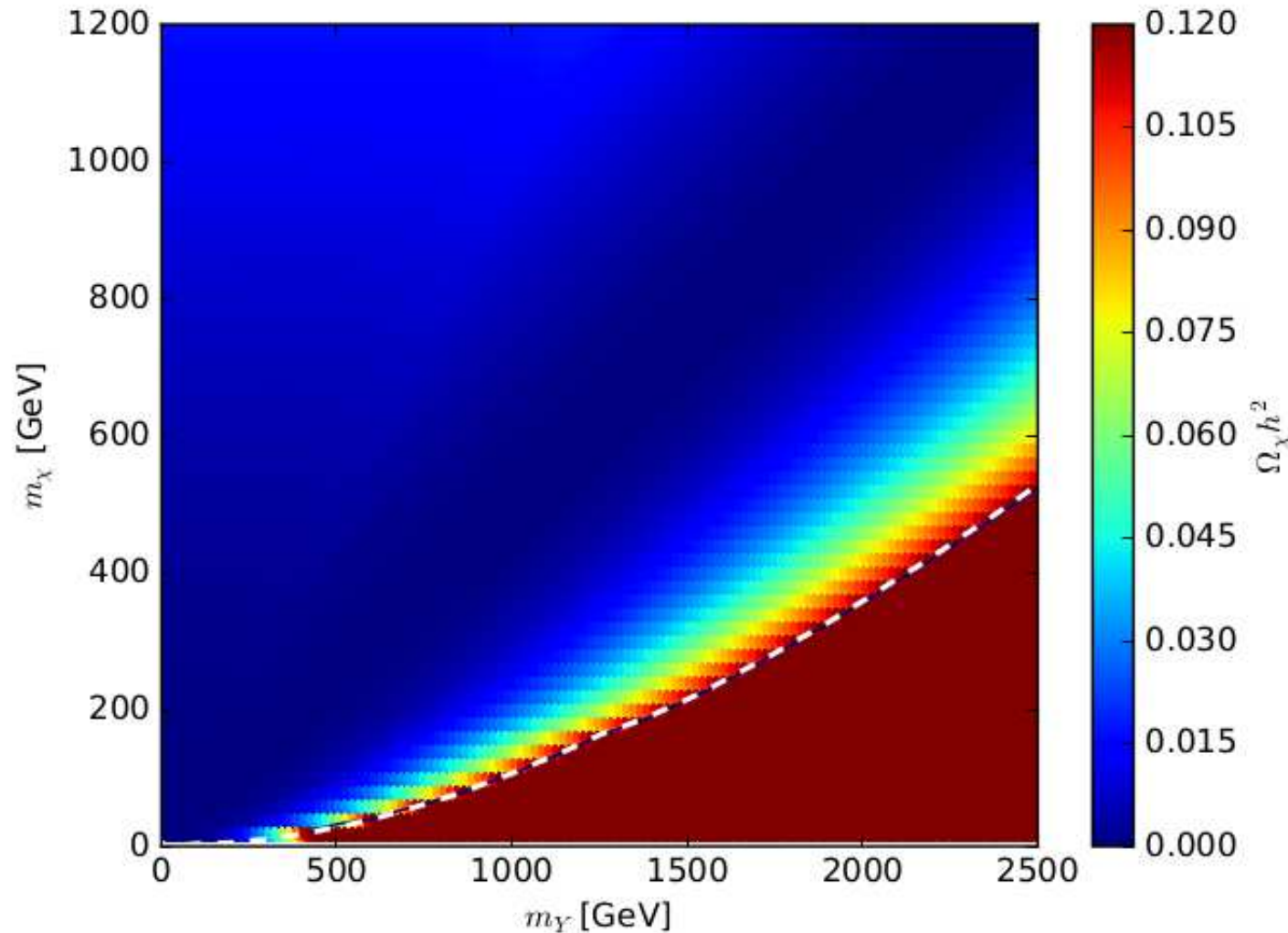
- Frequentist fitting framework written in Python/Cython and C++
- Multinest algorithm is used to sample the parameter space
- udocker used for deployment

Scan ranges:

Parameter	Range	# of Segments
m_Y (mediator)	(0.1, 5) TeV	10
m_χ (DM)	(0, 2.5) TeV	8
g_{SM}	$(10^{-6}, \sqrt{4\pi})$	2
g_{DM}	$(10^{-6}, \sqrt{4\pi})$	2
Total # of segments		320

DM constraints:

⇒ **micrOMEGAs** for relic density and DD cross sections

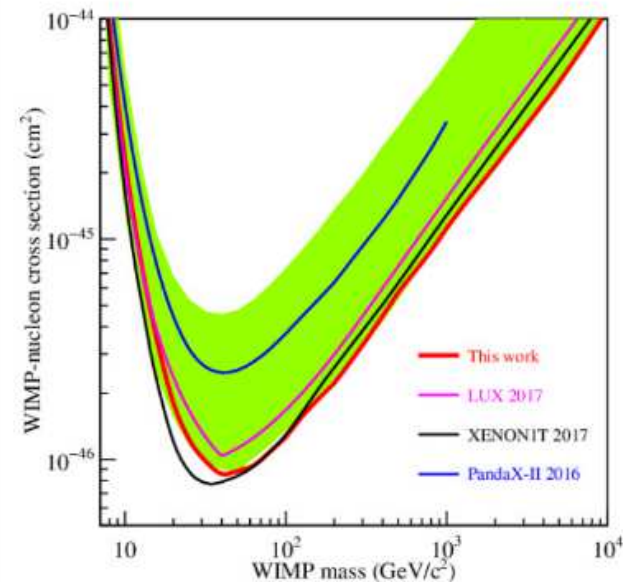
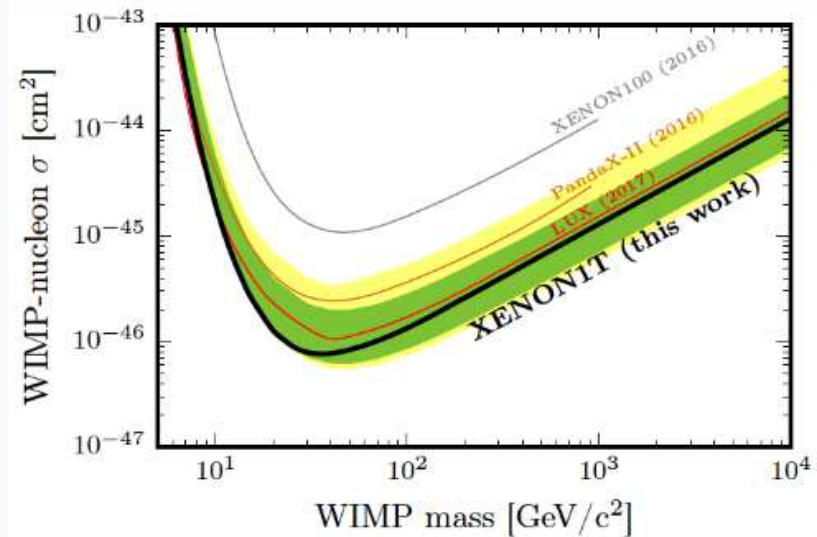
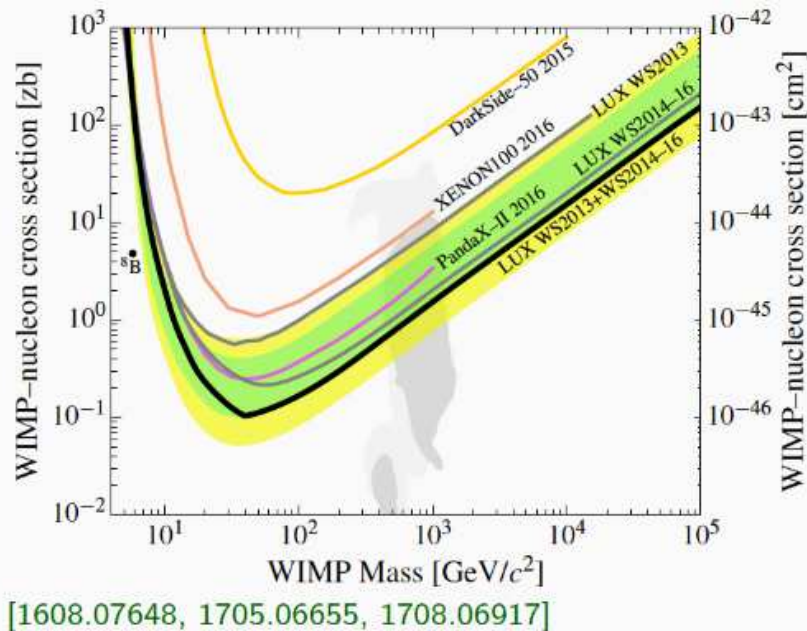


⇒ **full agreement** with ATLAS/CMS results (here: vector model)

Non-LHC constraints

Dark matter

- Relic density constraints from Planck.
- Direct detection constraints on σ_p^{SI} from LUX, XENON1T and PANDAX.
- Direct detection constraints on σ_p^{SD} from PICOD60.

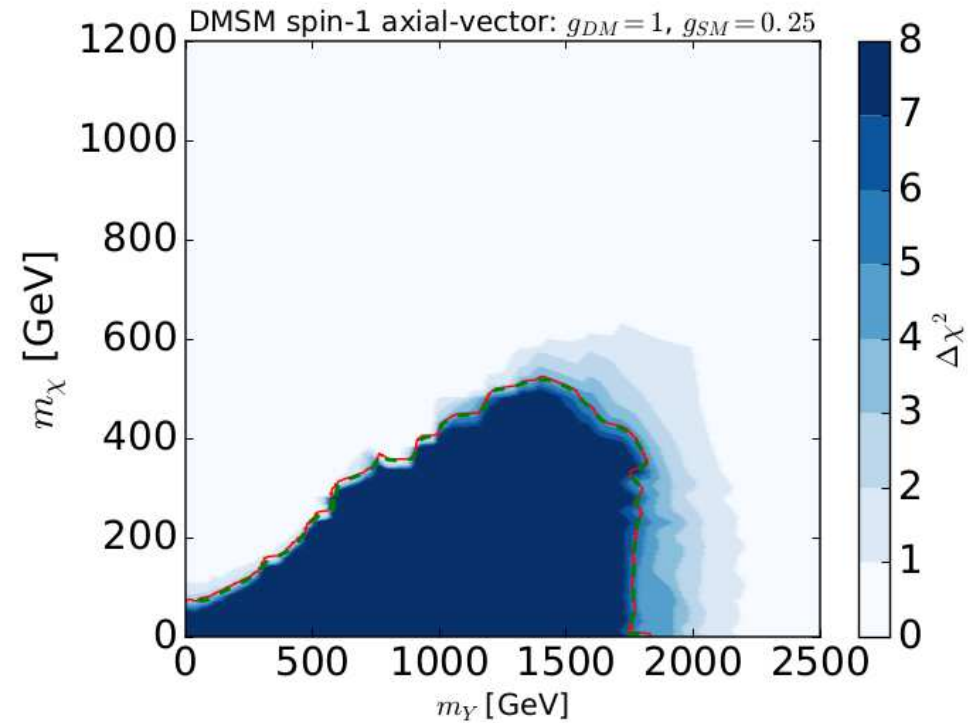
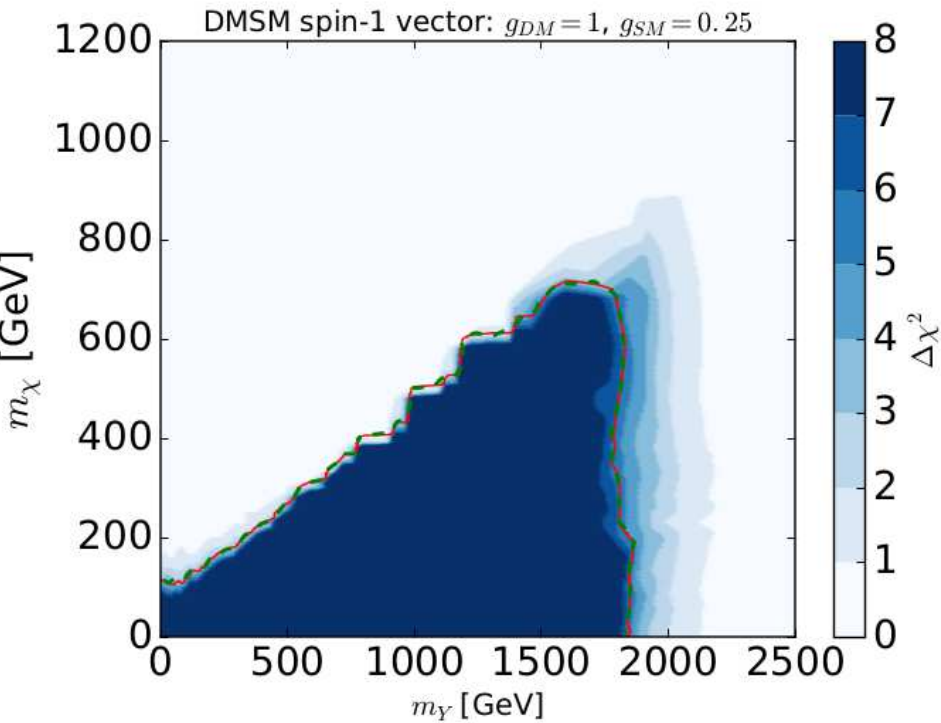


[taken from E. Bagnaschi]

Mono-jet constraints

[PRELIM.]

⇒ MG5 aMC(N)LO, Fastlim approach

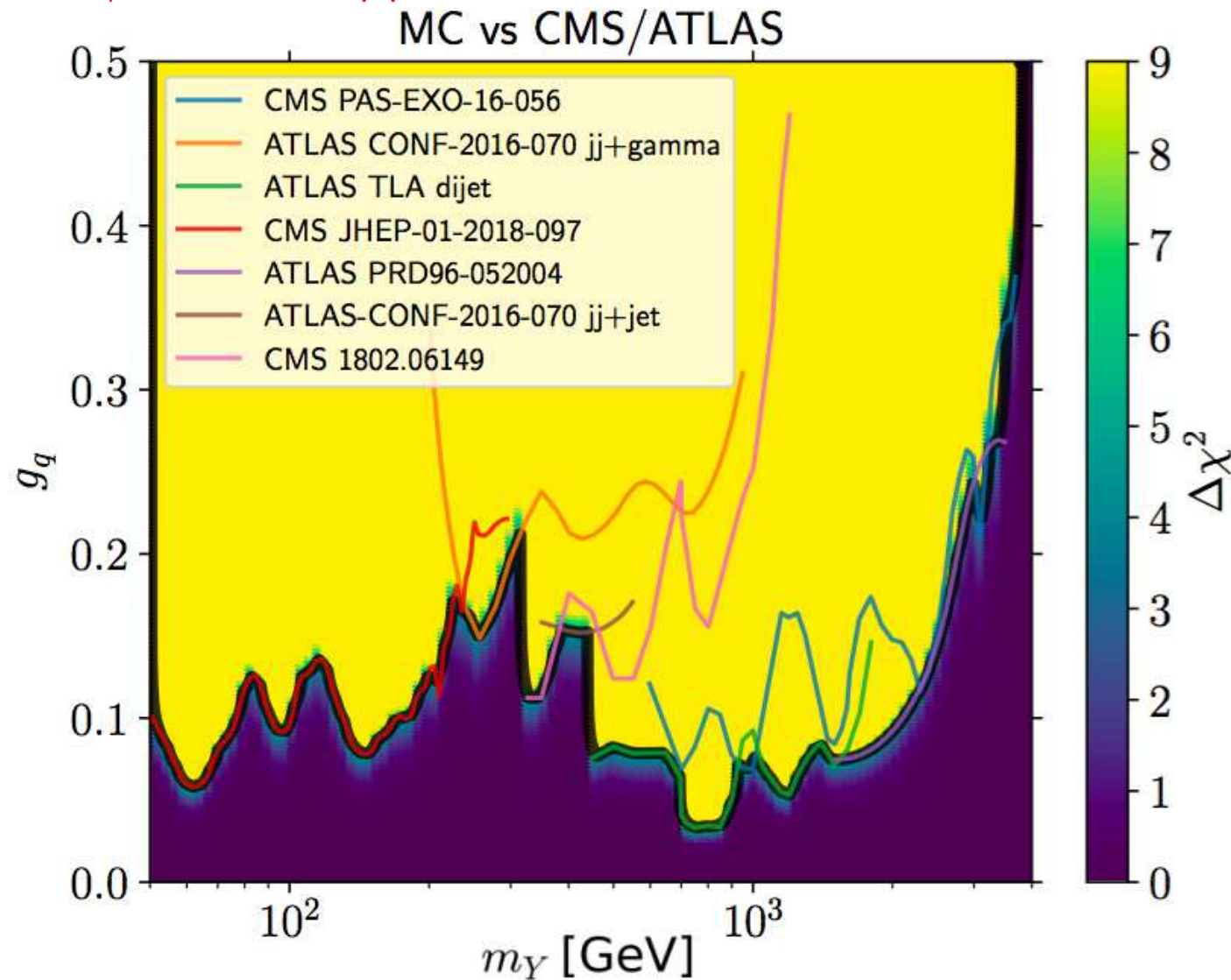


⇒ full agreement with ATLAS/CMS (red-dashed)

Di-jet constraints

⇒ MG5 aMC(N)LO, Fastlim approach

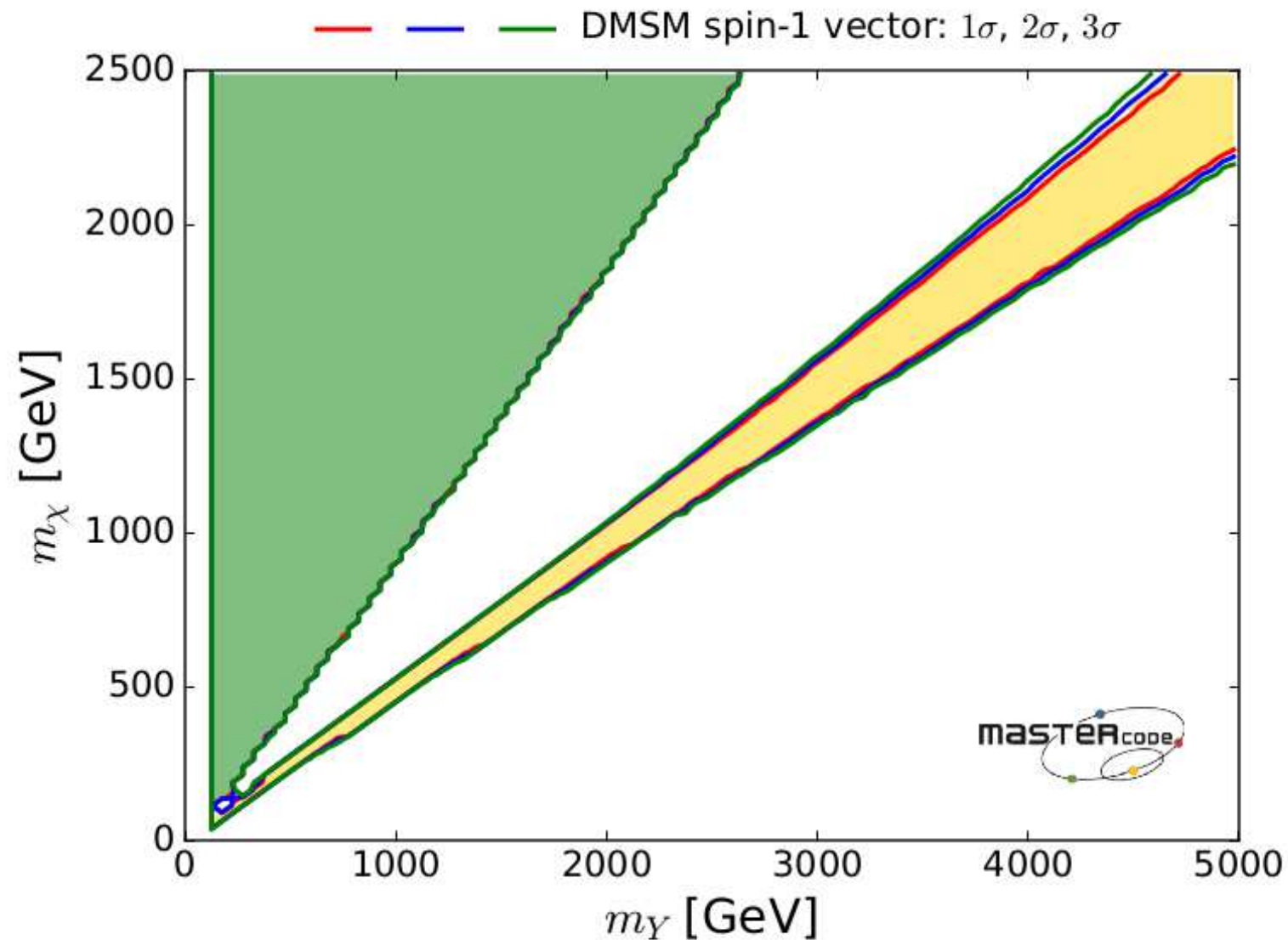
[PRELIM.]



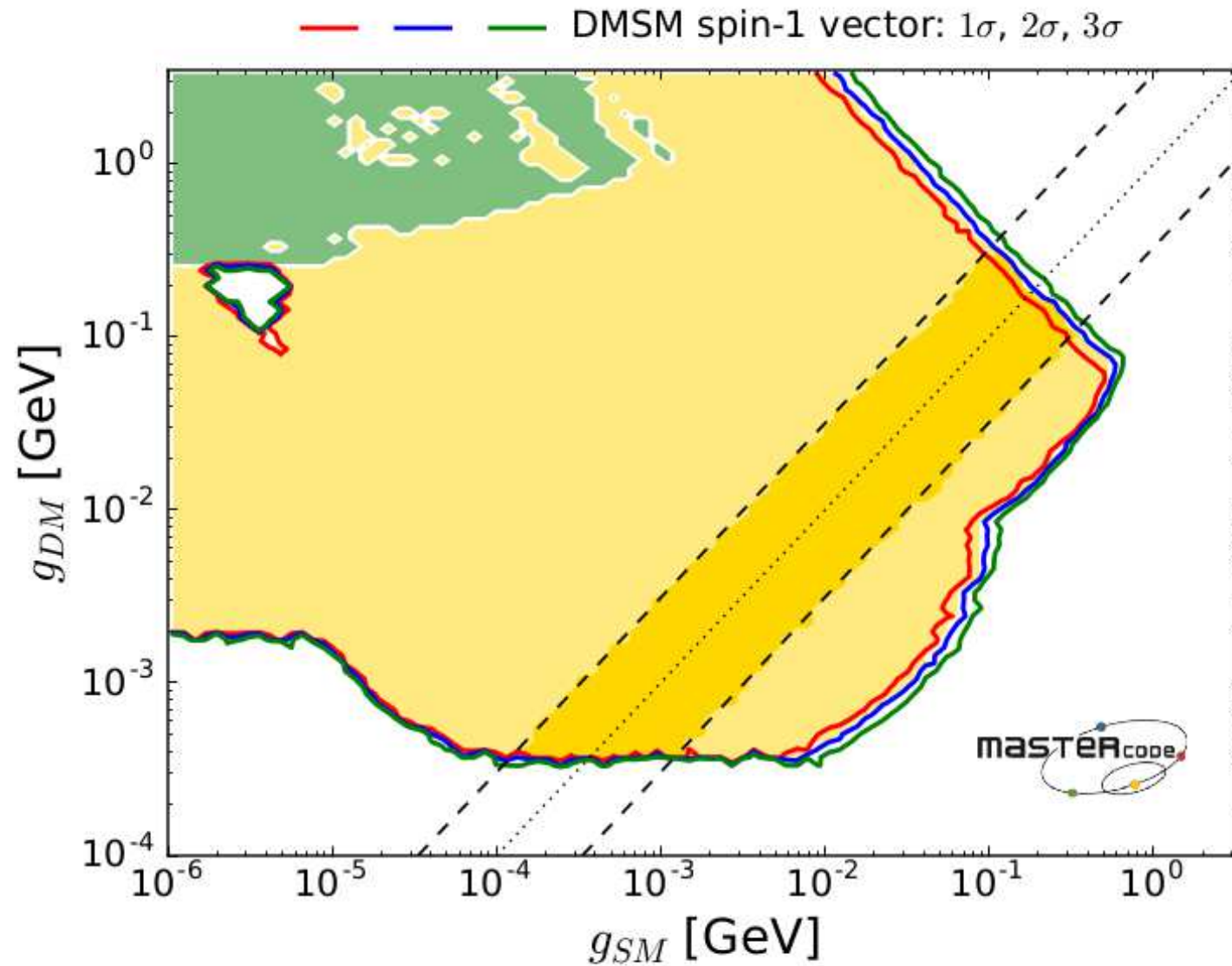
⇒ full agreement with ATLAS/CMS

3. General Results

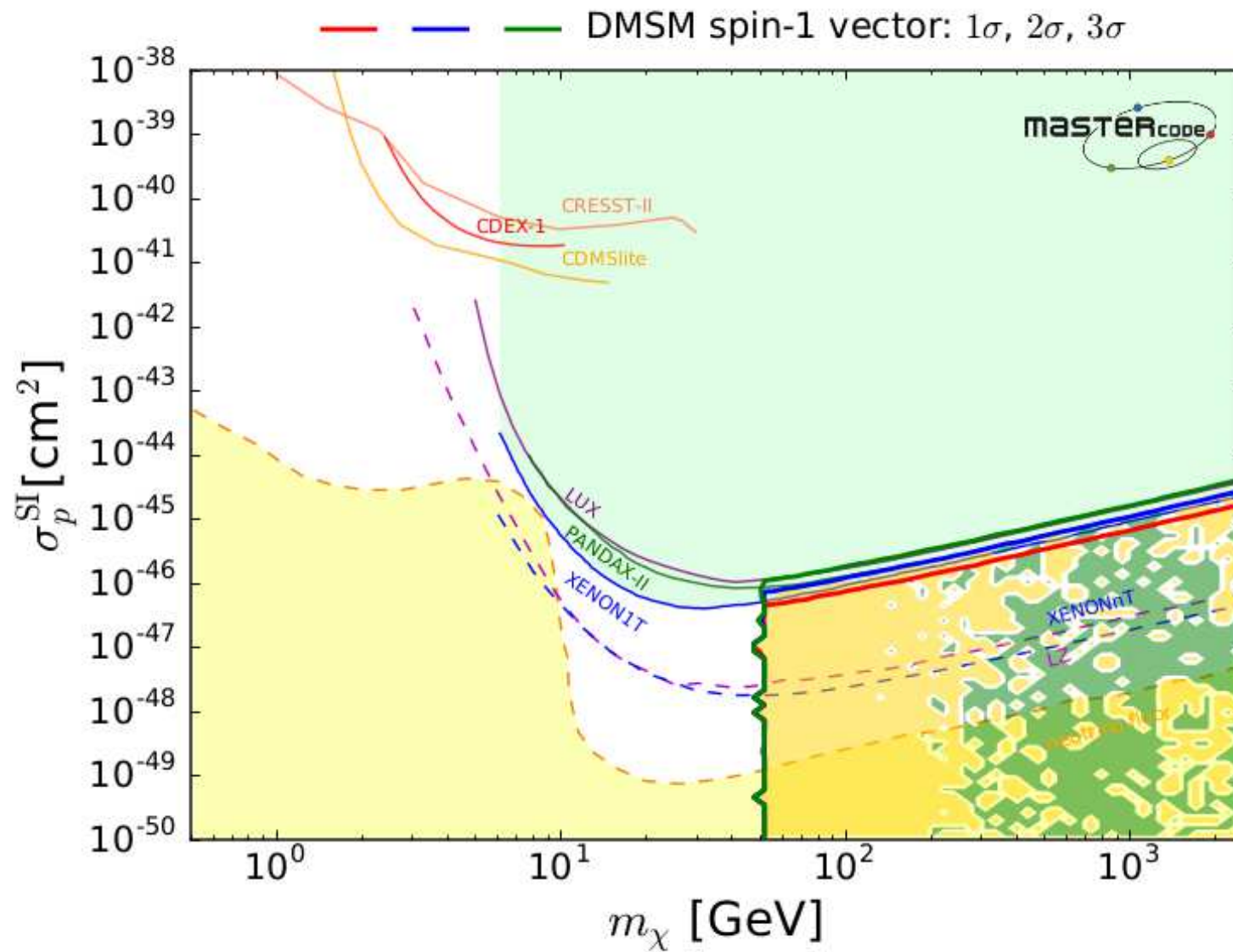
- Results for vector mediator model
- Results for axial-vector mediator model
- No restrictions on couplings or masses
- Color coding:
 - green: annihilation via t -channel χ exchange
into pairs of mediator particles Y that subsequently decay
into SM particles
 - yellow: rapid annihilation directly into SM particles
via the s -channel Y resonance



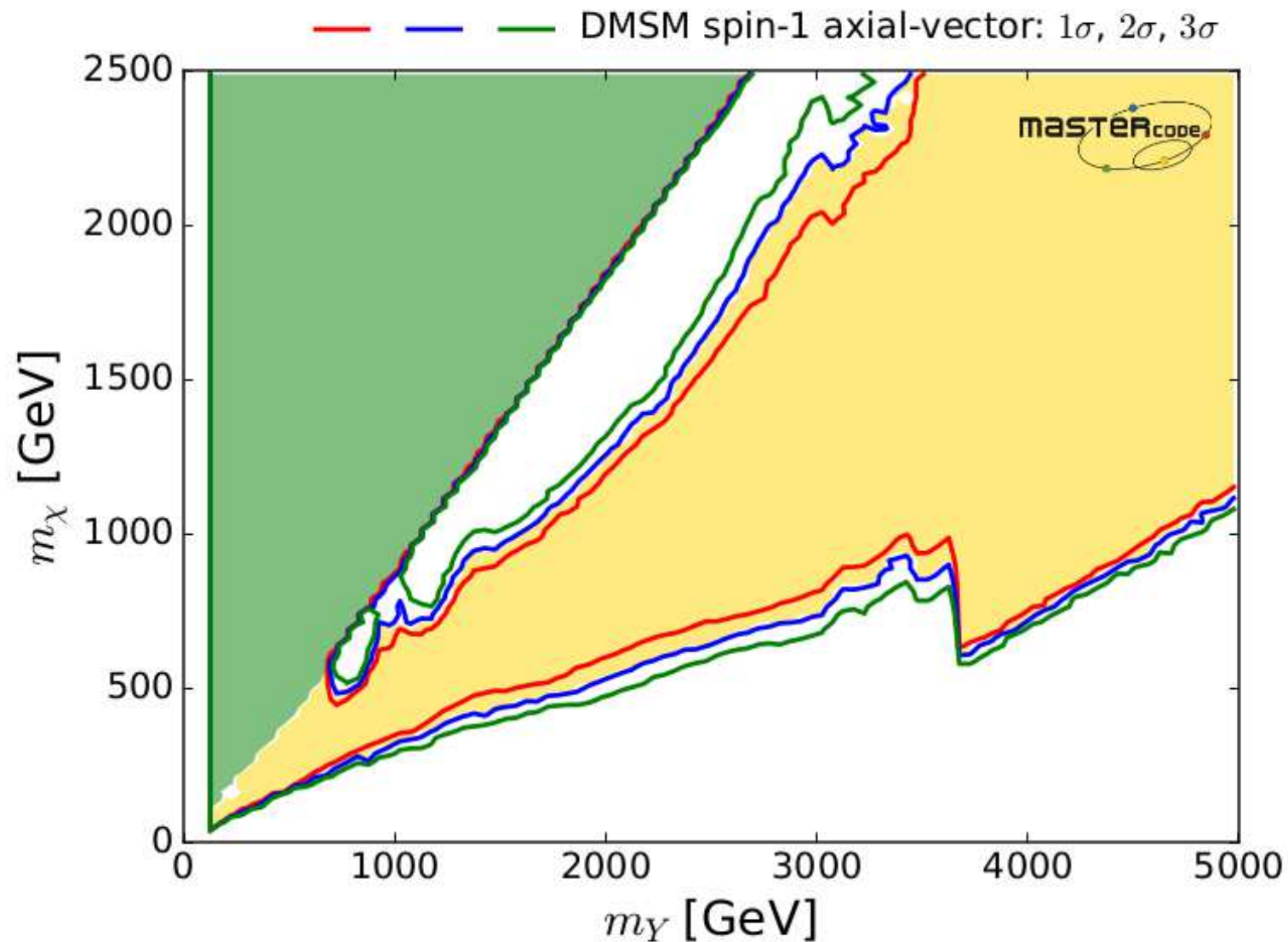
⇒ clear separation between s - and t -channel



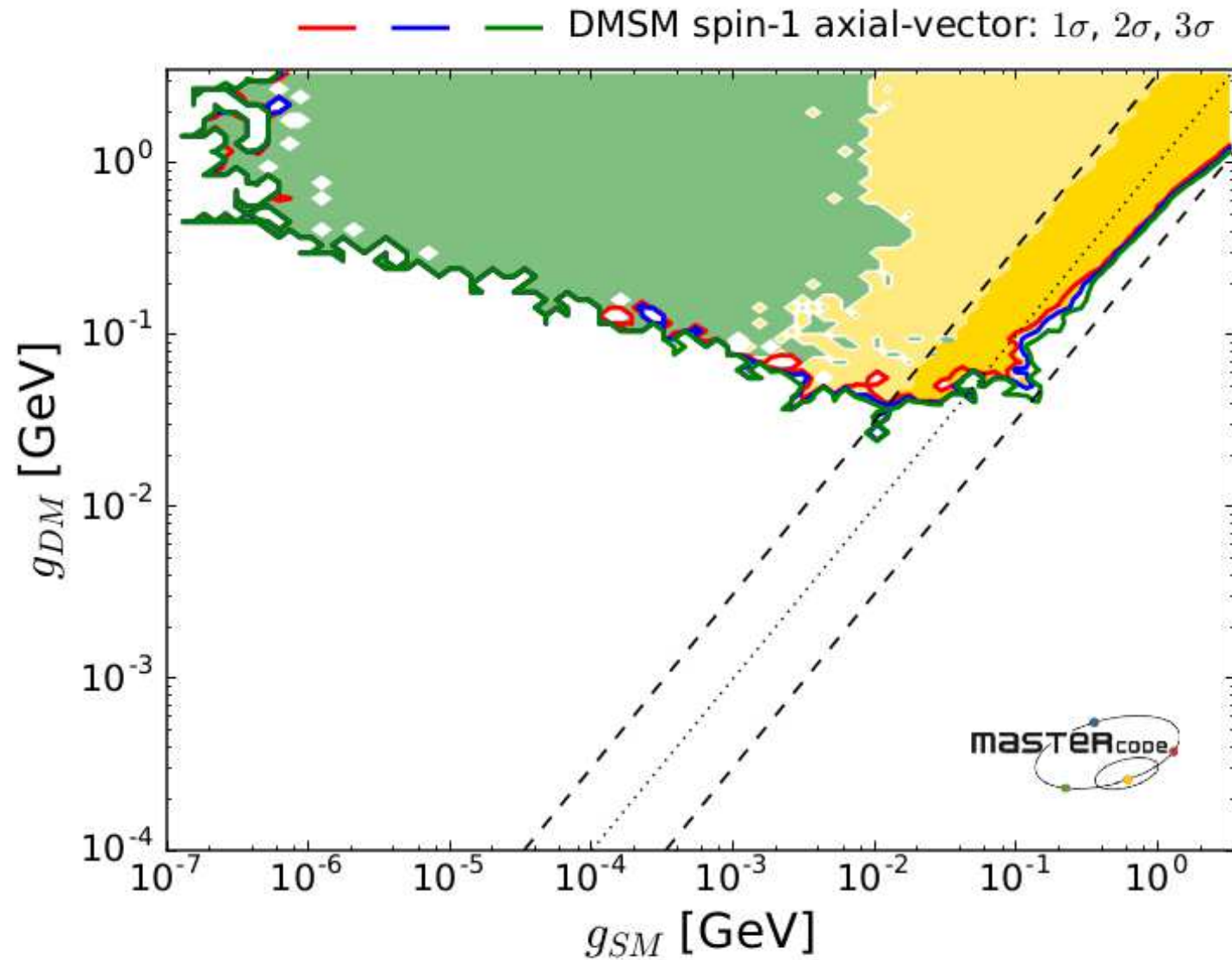
⇒ large ranges allowed, t -channel only for $g_{DM} \gg g_{SM}$



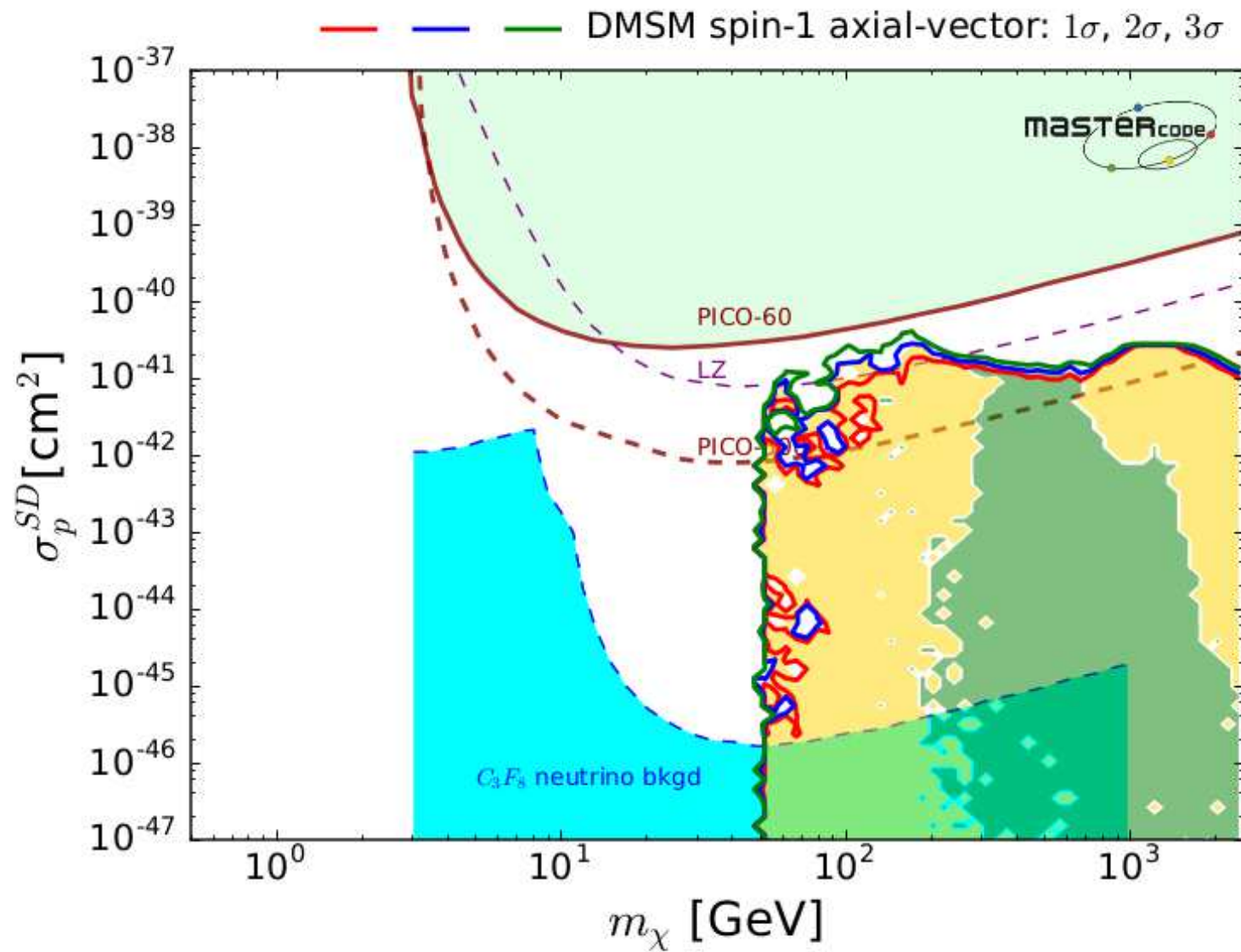
⇒ mixed prospects, both for s - and t -channel case



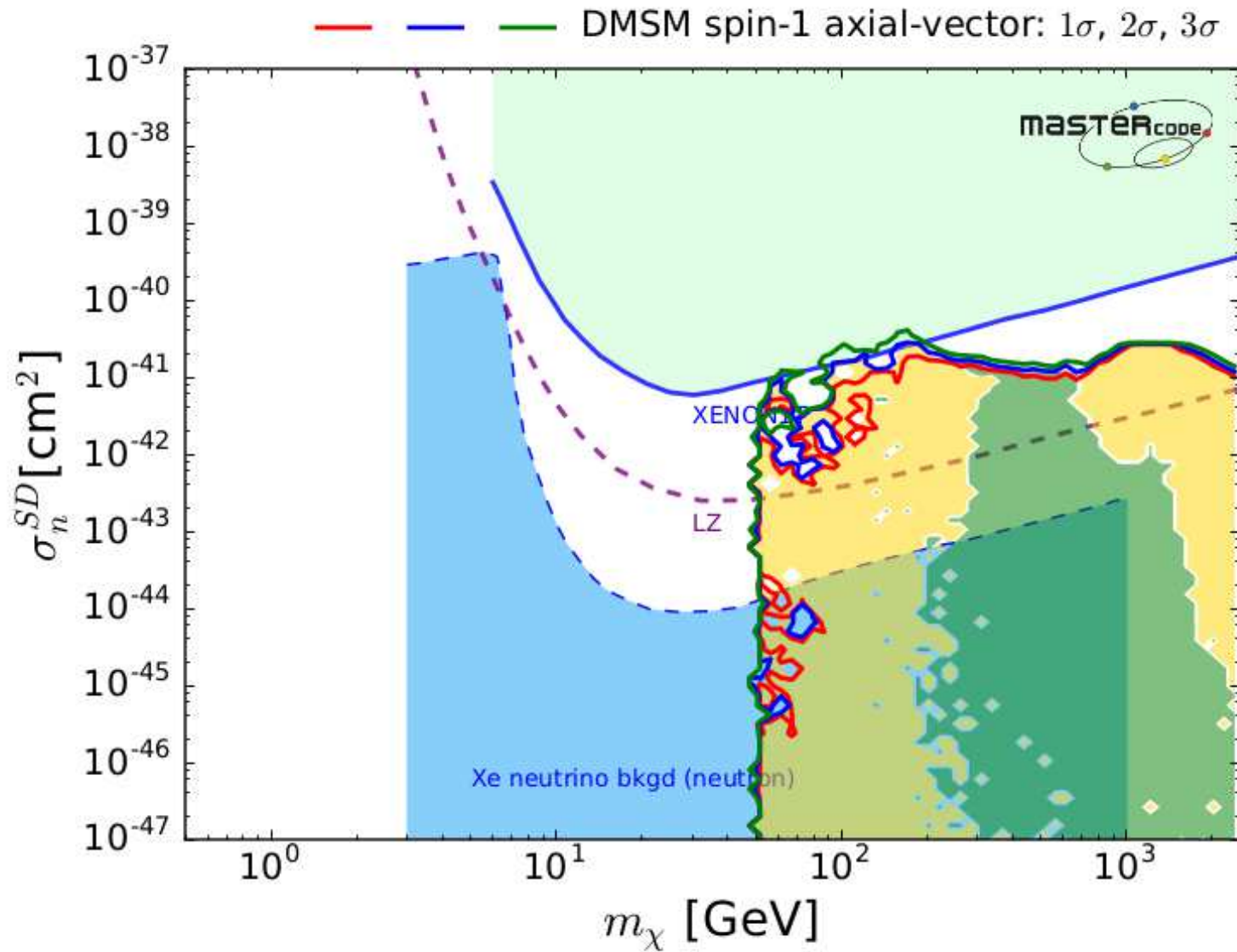
⇒ Larger s -channel region, continuous with t -channel



$\Rightarrow t$ - (s -)channel for $g_{SM} \lesssim (\gtrsim) 10^{-2}$



⇒ will not be easy for PICO!



⇒ neither for LZ!

4. Towards UV completions

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In any UV completion the spin-one boson could be expected to have comparable couplings to SM and DM particles, modulo possible group-theoretical factors and mixing angles!

$$g_{\text{DM}}/g_{\text{SM}} = \mathcal{O}(1)$$

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So far no UV completion considered!

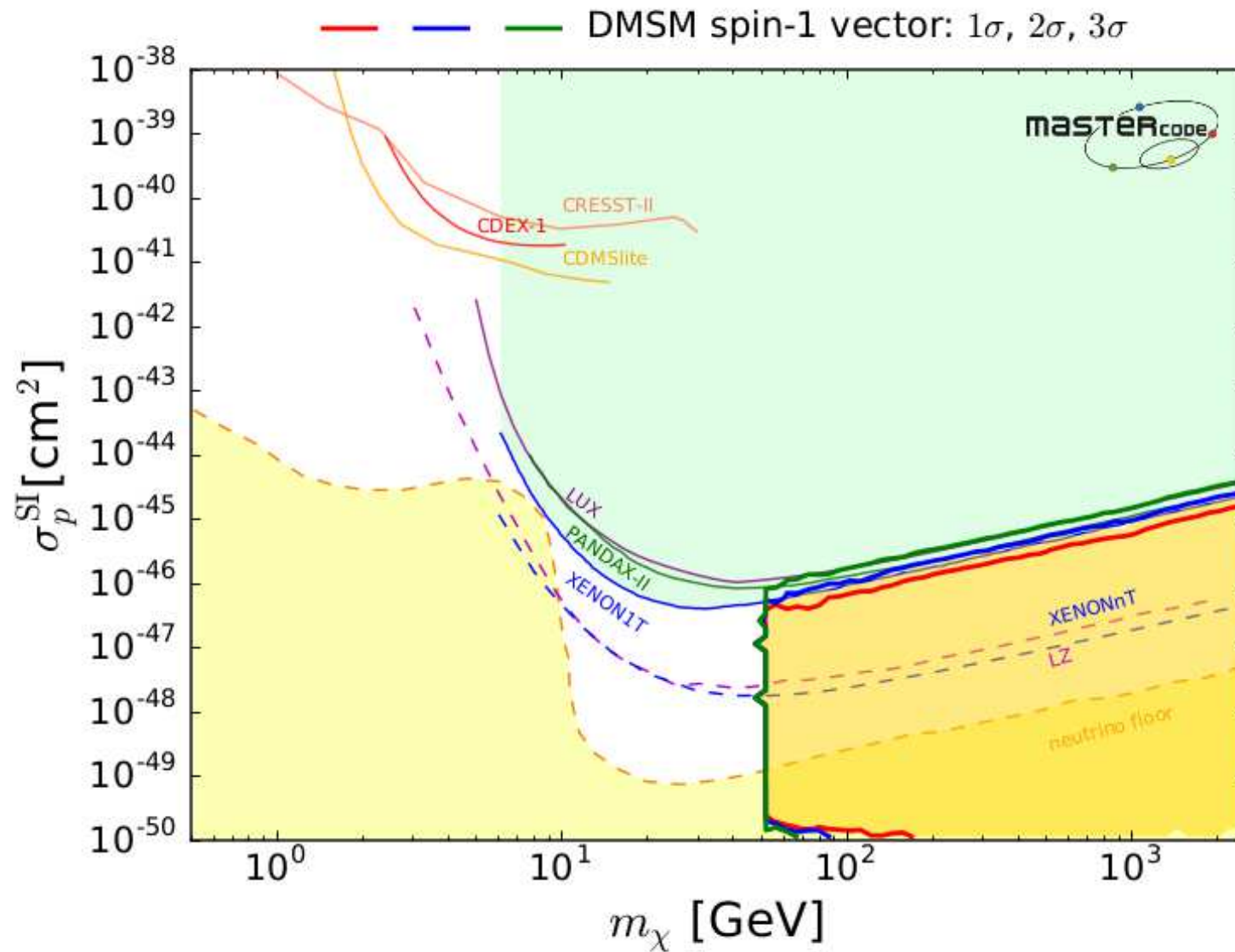
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$$g_{\text{DM}}/g_{\text{SM}} = \mathcal{O}(1)$$

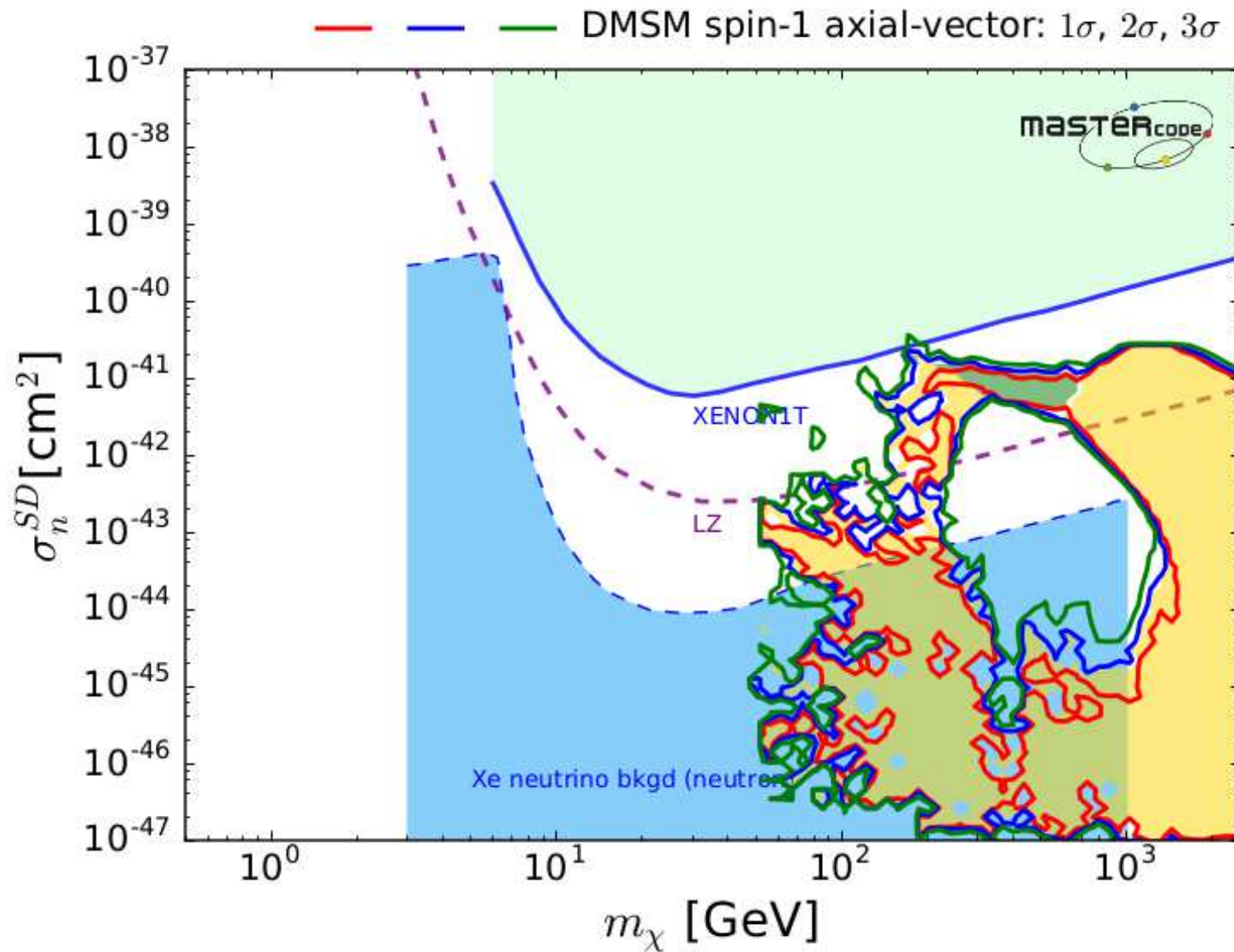
$$1/3 < g_{\text{DM}}/g_{\text{SM}} < 3$$

⇒ dark yellow regions

⇒ *s*-channel favored!



⇒ mixed prospects for discovery



⇒ t -channel can fully be probed, s -channel only partially

5. Conclusions

- EFT vs. **DMSM** vs. full theories
- Lagrangian for **vector** or **axial-vector** mediator
- So far results presented for **fixed values** for some of g_{SM} , g_{DM} , m_{med} , m_{DM} and other constraints (**mono-jet**, **di-jet**) overlaid
- **MasterCode approach: full fit of the model**, including
 - DM relic density
 - DM direct detection limits
 - LHC mono-jet searches
 - LHC di-jet searches
- Vector mediator: s - and t -channel separated, **mixed prospects** for DD
- Axialvector: s - and t -channel continuous, **mixed prospects** for DD
- UV-completions: $1/3 < g_{SM}/g_{DM} < 3 \Rightarrow s$ -channel preferred
 \Rightarrow prospects for DD **not improved**



Further Questions?